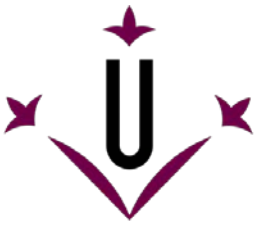


RECORD BREAKING MUSHROOM YIELDS IN SPAIN

Josu G. Alday[1], José Antonio Bonet[1,2], Juan Andrés Oria-de-Rueda[3,4], Juan Martínez-de-Aragón[2], Jorge Aldea[3,4], Pablo Martín-Pinto[3,4], Sergio de-Miguel[1], María Hernández-Rodríguez[3,4], Fernando Martínez-Peña[5,6,7]

[1] Department of Crop and Forest Sciences - Agrotecnico Center, Universitat de Lleida (UdL-Agrotecnio), Avda. Rovira Roure, 191, E-25198 Lleida, Spain

[2] Centre Tecnològic Forestal de Catalunya (CTFC-CEMFOR). Ctra. de St. Llorenç de Morunys km 2, E-25280 Solsona, Spain

[3] Instituto Universitario de Gestión Forestal Sostenible (UVA-INIA). Avda. Madrid, s/n, E-34004 Palencia, Spain

[4] Escuela Técnica Superior de Ingenierías Agrarias de Palencia (ETSIIA), Universidad de Valladolid (UVA). Avda. Madrid, s/n, E-34004 Palencia, Spain

[5] Agrifood Research and Technology Centre of Aragon CITA, 50059 Zaragoza, Spain.

[6] European Mycological Institute (EGTC-EMI). 42003, Soria, Spain

[7] Micocyl-Junta de Castilla y León-Fundación Cesefor. 42004, Soria, Spain.

Correspondence author: Josu G Alday

e-mail: jgalday@pvcf.udl.cat; josucham@gmail.com

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

Abstract

Despite the assumption that mushroom fruiting is dependent on climate conditions, recent changes in temperature and precipitation regimes in Mediterranean-type ecosystems opened new questions about how climate changes impact epigeous sporocarps yields. Here, we described the epigeous fungal sporocarp yield anomalies together with temperature and precipitation fluctuations that have triggered atypical fungal production peaks during the last 20 years in different forest ecosystems of Mediterranean Spain. We used the largest standardized, spatio-temporal epigeous sporocarp collection dataset available in Mediterranean-type forest ecosystems and climates. Two clear positive yield anomalies were found in 2006 and 2014, representing more than 270% and 210% increase, respectively, in comparison with time-series mean annual fungal yields. Late-summer-early-autumn precipitation was the most influential variable triggering these extreme mushroom production peaks in comparison with temperature. This suggests that fungal fruiting is sensitive to late-summer-early-autumn precipitation pulses, producing discrete yield pulses when conditions are optimal, which are interspersed among periods of limited water resource availability and lower yields.

Keywords: Sporocarp production, Fungi, Non-wood forest products, Climate, Variability, Pulses

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

1. Introduction

Fungi have significant effects on both ecosystem processes and services at scales ranging from local to global. Ectomycorrhizal fungi in symbiosis with tree roots directly influence nutrient and water availability for trees (Smith and Read, 2008). In contrast, saprotrophic fungi are responsible for organic matter decomposition (Eastwood et al., 2011), being fundamental in soil carbon storage in soil-plant systems (Clemmensen et al., 2013). Fungi are a great source of biodiversity and ecosystem services (regulation, provisioning and cultural), contributing significantly to maintain local livelihoods based on mushroom picking and related markets (Ágreda et al., 2015). In addition, wild mushrooms are becoming a cornerstone in the development of multifunctional forest ecosystem programmes in several countries, being a good example of the increasing relevance of non-wood forest products in forest policies.

Nowadays, there is agreement that mushroom fruiting is dependent on climate conditions (precipitation and temperature, Büntgen et al., 2011). However, during the last century, both temperature and precipitation regimes have changed worldwide, producing important shifts in habitat preferences of species (Root et al., 2003) and, thus, alterations in mushroom yields (Kauserud et al., 2008). In this regard, how climate impacts epigeous sporocarp yields, and what the fruiting pattern is, are knowledge gaps that need to be filled, essentially in Mediterranean-type ecosystems (Lindner et al., 2010). For example, in the western Mediterranean basin, where temperature and rainfall variability has increased, we would expected either (i) a decrease in productivity or (ii) an increase in sporocarp yield irregularity; however, the real yield response is unclear. In this paper, we describe the epigeous fungal sporocarp yield variability and anomalies during the last 20 y in different forest types of Mediterranean Spain, being the largest standardized, spatio-temporal epigeous sporocarp collection dataset available in the

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

world. At the same time, we try to identify the particular climatic conditions (precipitation and temperature) that trigger mushroom production anomalies.

2. Materials and Methods

2.1. Study sites

Since 1995 different forest stands (*Pinus sylvestris, P. pinaster, P. nigra, P. halepensis, Quercus ilex* and *Cistus ladanifer*) have been selected in Spain to establish permanent plots sampling scheme, aiming to describe sporocarp yields in Mediterranean forest over time. Now, up to 140 permanent plots are monitored yearly in three different regions of Spain: (i) 87 plots in Catalonia (North-eastern), 1997-2001 & 2007-2015; (ii) 32 plots in Eastern Castilla y León (Eastern-CyL; North-central), 1995-2015; and (iii) 21 plots in Western-central Castilla y León (Western-CyL; North-western), 2003-2015. The full descriptions of study areas and sampling methodology are detailed in: de-Miguel et al. (2014) for Catalonia, Martínez-Peña et al. (2012) and Taye et al. (2016) for Eastern-CyL, and Gassibe et al. (2015) and Hernández-Rodríguez et al. (2015) for Western-CyL (Supplementary Appendix 1).

2.2. Sampling methods

The plots were sampled at 1-week intervals from the beginning of September to the end of December (yield period). Each week, all epigeous sporocarps were counted and harvested from each of the 140 plots. In the laboratory, collected sporocarps were taxonomically identified at species level by morphological features and then fresh-weighted. When it was not possible to identify species, sporocarps were identified at genus level. A complete list of recorded species is included in Supplementary Appendix

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

2. Simultaneously, species were also classified according to their trophic strategy, i.e. mycorrhizal and saprotrophic, based on the existing literature and expert knowledge (Tedersoo et al., 2010). In addition, the sporocarps of edible fungi were also classified as either marketed or non-marketed species. Climatic data were obtained from the nearest meteorological station to each plot. Here, we only considered the accumulated precipitation and mean temperature from August 1 to October 30 to characterize the main seasonal drivers of "late-summer and early-autumn" (LSEA) epigeous sporocarps fruiting.

2.3. Statistical analysis

All statistical analyses were performed in R statistical environment (3.2.2 R Core Team, 2015). Anomalies detection analysis over different yield time-series datasets was performed using Anomaly Detection package (Vallis et al., 2014), which is based on Generalized Extreme Studentized Deviate Test (α=0.05). Mushroom yields and climatic variables relationships were analysed using two approaches: (i) linear regression between overall mean annual sporocarps yield and LSEA precipitation and temperature and (ii) cross-correlation of mean annual sporocarps yield *vs*. precipitation or temperature time-series.

3. Results and Discussion

The analysis of the complete epigeous sporocarp yield time-series reveals the existence of two significant positive anomalies in the sequence (Supplementary Fig. 1a). The first one in 2006 with a total maximum yield of 324.11±35.95 kg-ha^{-1}, which was recorded only in Eastern- and Western-CyL (Table 1; Catalonian data was not available). The second significant anomaly was produced in 2014 (271.10±17.45 kg-ha^{-1}), with

identical yield increases in all studied regions. It is interesting to highlight that the mean yield value along the time series, not considering the anomaly years, was 87.28±3.12 kg-ha^{-1}. Therefore, the abnormal years showed a yield increase of 271% and 210%, respectively (Table 1). The 2006 and 2014 significant positive anomalies were also found when the data were split in mycorrhizal and saprotrophic functional guilds (Supplementary Appendix 3), as well as when marketed and non-marketed groups of edible fungi were considered, especially in 2014 (Table 1).

The climatic analysis showed that the total epigeous sporocarp yield was significantly related with LSEA precipitation ($F_{[1,19]}$=4.57, p-value<0.046), but not with temperature ($F_{[1,19]}$=3.02 p-value=0.100). Simultaneously, yield and LSEA precipitation time-series were significantly correlated (cross-correlation $p<0.05$ only at lag 0; Supplementary Appendix 3), being 2014 LSEA precipitation also an anomaly (322.40±8.03mm, 51% increase), while 2006 LSEA precipitation not being an anomaly was greater than the precipitation time-series-mean values (263.86±9.47 vs. 221.50±2.11). LSEA temperature showed a lack of cross-correlation with yield ($p>0.05$), although November mean temperature showed a slight correlation ($p\sim0.05$) with yield, suggesting that high temperatures in mid- to late-autumn can contribute to expand the fruiting period. In any case, changes in rainfall during the LSEA fruiting period altered epigeous fungi sporocarp yields (Martínez-Peña et al., 2012). The occurrence of years with average sporocarp yield values around the time-series mean (87.28±3.12) and years with extreme yield peaks (2006-2014), the later being associated with high LSEA precipitation, suggest that fungal fruiting is sensitive to water resource availability pulses. Therefore, years when LSEA precipitation is abundant have a positive impact on fungal fruiting as discrete pulse events, which are interspersed among periods of limited resource availability and lower yields.

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

Fungal fruiting patterns in Mediterranean-type ecosystems are the result of long-term evolutionary adaptation to an annual repeatable climatic pattern of wet autumn season following a summer drought (Barnard et al., 2015). Thus, the increase in precipitation irregularity and extreme rainfall events produced by climate change (Kauserud et al., 2008) have been hypothesized to cause decreases in epigeous sporocarp yields over time (Ágreda et al., 2015). Our results suggest that instead of a yield reduction, fruiting productivity patterns are responding to LSEA moisture, so if climate change alters the frequency of precipitation events in LSEA, fungal fruiting will likely respond accordingly.

Finally, the maximum sporocarp yield values reported are a fundamental result to evaluate ecosystem services (Table 1). Nowadays, environmental integrative indexes at landscape level have been developed to be operationally simple (see: MESLI, Rodríguez-Loinaz et al., 2015). However, some ecosystem services indicators, such as sporocarps yields, do not have clear high performance benchmarks (maximum). Therefore, our identification of sporocarp yield high benchmarks for the 20 y period can help to quantify more accurately the year-to-year amount of services provided by fungi as NWFP. In conclusion, the evidence reported here suggests that epigeous sporocarp fruiting is adapted to late-summer-early-autumn precipitation patterns, producing clear pulses when the conditions are optimal. These yield pulses are interspersed among periods of limited water resource availability and lower yields, which are predicted to be more frequent in the future.

Acknowledgements

This study was partially funded by the research project AGL2012-40035-C03 (MCI Spain), by VA206U13 (Junta-CyL) and European project StarTree-Multipurpose-trees (No-311919). JGA was supported by Juan de la Cierva-fellowship (IJCI-2014-21393), SdM by the European Union's Horizon 2020 MultiFUNGtionality Marie Skłodowska-Curie (IF-EF No-655815) and JAB benefit from Serra-Hunter Fellow provided by the Generalitat of Catalunya.

References

Ágreda, T., Águeda, B., Olano, J.M., Vicente-Serrano, S.M., Fernández-Toirán, M., 2015. Increased evapotranspiration demand in a Mediterranean climate might cause a decline in fungal yields under global warming. Glob. Change Biol. 21, 3499-3510.

Barnard, R.L., Osborne, C.A., Firestone, M.K., 2015. Changing precipitation pattern alters soil microbial community response to wet-up under a Mediterranean-type climate. ISME 9, 946-957.

Büntgen, U., Kauserud, H., Egli, S., 2011. Linking climate variability to mushroom productivity and phenology. Front. Ecol. Environ. 10, 14-19.

Clemmensen, K.E., Bahr, A., Ovaskainen, O., Dahlberg, A., Ekblad, A., Wallander, H., Stenlid, J., Finlay, R.D., Wardle, D.A., Lindahl, B.D., 2013. Roots and associated fungi drive long-term carbon sequestration in boreal forest. Science 339, 1615-1618.

de-Miguel, S., Bonet, J.A., Pukkala, T., Martínez-de-Aragón, J., 2014. Impact of Forest management intensity on landscape-level mushroom productivity: A regional model-based scenario analysis. For. Ecol. Manage. 330, 218-227.

Eastwood, D.C., Floudas, D., Binder, M., Majcherczyk, A., Schneider, P., Aerts, A., Asiegbu, F.O., Baker, S.E., Barry, K., Bendiksby, M., Blumentritt, M., 2011. The plant cell wall–decomposing machinery underlies the functional diversity of forest fungi. Science 333, 762-765.

Gassibe, P.V., Oria-de-Rueda, J.A., Martín-Pinto, P., 2015. *P. pinaster* under extreme ecological conditions provides high fungal production and diversity. For. Ecol. Manage. 337, 161-173.

Hernández-Rodríguez, M., de-Miguel, S., Pukkala, T., Oria-de-Rueda, J.A., Martín-Pinto, P., 2015. Climate-sensitive models for mushroom yields and diversity in *Cistus ladanifer* scrublands. Agric. For. Meteorol. 213, 173-182.

Kauserud, C.L., Stige, J.O., Vik, J.O., Okland, R.H., Hoiland, K, Stenseth, N.C., 2008. Mushroom fruiting and climate change. PNAS 105, 3811-3814.

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M.J., Marchetti, M., 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecol. Manag. 259, 698-709.

Martínez-de-Aragón, J., Oliach, D., Henriques, R., Fortuny, M., Girbal, J., Bonet, J.A., 2012. Manual de buenas prácticas para la gestión del recurso micológico forestal. CTFC, Lleida.

Martínez-Peña, F., de-Miguel, S., Pukkala, T., Bonet, J.A., Ortega-Martínez, P., Aldea, J., Martínez-de-Aragón, J., 2012. Yield models for ectomycorrhizal mushrooms in *Pinus sylvestris* forests with special focus on *Boletus edulis* and *Lactarius* group *deliciosus*. For. Ecol. Manage. 282, 63-69.

R Core Team, 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Rodríguez-Loinaz, G., Alday, J.G., Onaindia, M., 2015. Multiple ecosystem services landscape index: a tool for multifunctional landscapes conservation. J. Environ. Manage. 147, 152-163.

Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C., Pounds, J.A., 2003. Fingerprints of global warming on wild animals and plants. Nature 421, 57-60.

Smith, S.E., Read, D.J., 2008. Mycorrhizal symbiosis. Academic Press, London.

Taye, Z.M., Martínez-Peña, F., Bonet, J.A., Martínez-de-Aragón, J, de-Miguel, S., 2016. Meteorological conditions and site characteristics driving edible mushroom production in *Pinus pinaster* forests of Central Spain. Fungal Ecol. 23, 30-41.

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

Tedersoo, L., Nilsson, R.H., Abarenkov, K., Jairus, T., Sadam, A., Saar, I., Bahram, M., Bechem, E., Chuyong, G., Kõljalg, U., 2010. Pyrosequencing and Sanger sequencing of tropical mycorrhizal fungi provide similar results but reveal substantial methodological biases. New Phytol. 188, 291-301.

Vallis, O.S., Hochenbaum, J., Kejariwal, A., 2014. AnomalyDetection: Anomaly detection using seasonal hybrid extreme studentized deviate test. R package version 1.0.

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

Table 1. Arithmetic mean values (kg ha^{-1}±SE) for sporocarp yield variables in the two anomalous years (2006 and 2014) and yield increases in percentage (Δ%) in relation to mean annual yield values of the time-series after removing the two anomalous years (TS-mean). Total yield is divided in ectomycorrhizal and saprotrophic sporocarp yields and in edible non marketed (edible-non-mktd) and edible marketed (marketed) yields.

		2006		2014	
	TS-mean	Mean	Δ%	Mean	Δ%
Total yield all regions	87.28±3.12	324.11±35.95	271.35	271.10±17.45	210.61
Ectomycorrhizal	73.24±2.90	300.39±36.69	310.15	229.32±16.68	213.11
Saprotrophic	10.51±0.61	23.72±5.79	225.69	25.15±3.08	139.30
Edible-non-mktd	26.90±1.33	35.12±6.01	30.56	100.86±10.28	274.94
Marketed	26.04±1.43	45.09±10.08	73.16	85.33±9.50	227.69
Catalonia Yield	68.63±3.59	-	-	212.52±19.17	209.66
Ectomycorrhizal	59.85±3.48	-	-	188.10±18.59	214.29
Saprotrophic	8.78±0.56	-	-	24.42±2.73	178.13
Edible-non-mktd	29.01±2.09	-	-	91.78±12.86	216.37
Marketed	23.09±1.96	-	-	74.27±11.94	221.65
Eastern-CyL yield	92.26±5.19	337.20±39.25	265.49	330.23±36.73	257.93
Ectomycorrhizal	83.50±4.96	312.46±41.13	274.20	303.13±35.98	263.03
Saprotrophic	8.75±1.21	24.74±8.23	182.74	27.19±10.28	210.74
Edible-non-mktd	18.55±1.29	38.92±7.36	109.81	88.83±16.85	378.87
Marketed	30.13±2.41	54.73±12.34	81.64	106.94±21.27	254.93
Western-CyL yield	179.24±13.93	297.93±76.96	66.22	426.04±47.22	137.69
Ectomycorrhizal	132.15±13.94	276.24±76.35	109.04	403.61±56.65	153.33
Saprotrophic	33.09±3.85	21.68±6.15	-	22.43±3.70	-
Edible-non-mktd	51.94±6.07	21.63±6.82	-	78.59±33.08	202.70
Marketed	25.01±3.79	10.81±5.12	-	98.70±22.50	294.64

Please cite this article in press as: Alday, J.G., et al., Record breaking mushroom yields in Spain, Fungal Ecology (2017), http://dx.doi.org/10.1016/j.funeco.2017.01.004

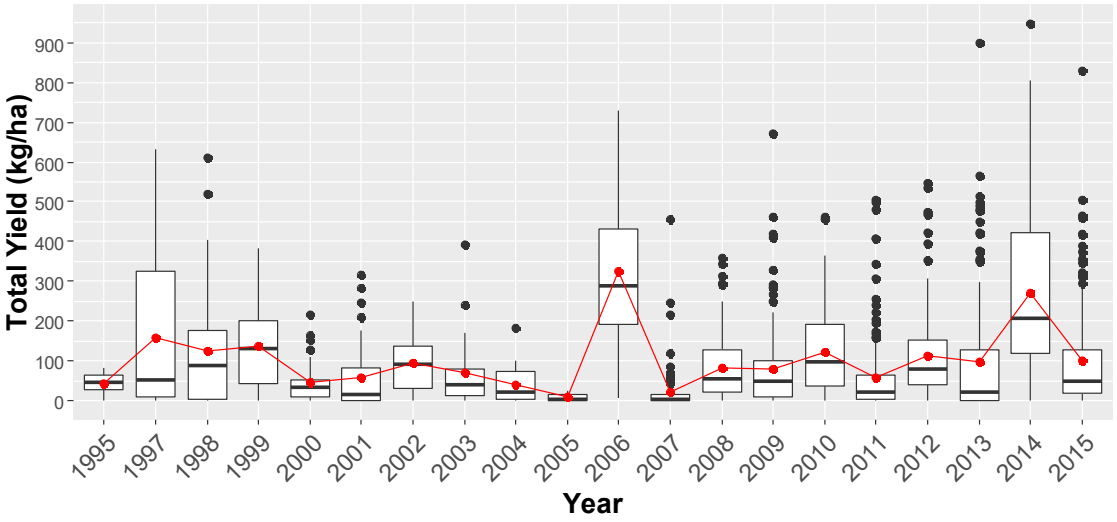
Table 1. Arithmetic mean values (kg ha^{-1}±SE) for sporocarp yield variables in the two anomalous years (2006 and 2014) and yield increases in percentage (Δ%) in relation to mean annual yield values of the time-series after removing the two anomalous years (TS-mean). Total yield is divided in ectomycorrhizal and saprotrophic sporocarp yields and in edible non marketed (edible-non-mktd) and edible marketed (marketed) yields.

		2006		2014	
	TS-mean	Mean	Δ%	Mean	Δ%
Total yield all regions	87.28±3.12	324.11±35.95	271.35	271.10±17.45	210.61
Ectomycorrhizal	73.24±2.90	300.39±36.69	310.15	229.32±16.68	213.11
Saprotrophic	10.51±0.61	23.72±5.79	225.69	25.15±3.08	139.30
Edible-non-mktd	26.90±1.33	35.12±6.01	30.56	100.86±10.28	274.94
Marketed	26.04±1.43	45.09±10.08	73.16	85.33±9.50	227.69
Catalonia Yield	68.63±3.59	-	-	212.52±19.17	209.66
Ectomycorrhizal	59.85±3.48	-	-	188.10±18.59	214.29
Saprotrophic	8.78±0.56	-	-	24.42±2.73	178.13
Edible-non-mktd	29.01±2.09	-	-	91.78±12.86	216.37
Marketed	23.09±1.96	-	-	74.27±11.94	221.65
Eastern-CyL yield	92.26±5.19	337.20±39.25	265.49	330.23±36.73	257.93
Ectomycorrhizal	83.50±4.96	312.46±41.13	274.20	303.13±35.98	263.03
Saprotrophic	8.75±1.21	24.74±8.23	182.74	27.19±10.28	210.74
Edible-non-mktd	18.55±1.29	38.92±7.36	109.81	88.83±16.85	378.87
Marketed	30.13±2.41	54.73±12.34	81.64	106.94±21.27	254.93
Western-CyL yield	179.24±13.93	297.93±76.96	66.22	426.04±47.22	137.69
Ectomycorrhizal	132.15±13.94	276.24±76.35	109.04	403.61±56.65	153.33
Saprotrophic	33.09±3.85	21.68±6.15	-	22.43±3.70	-
Edible-non-mktd	51.94±6.07	21.63±6.82	-	78.59±33.08	202.70
Marketed	25.01±3.79	10.81±5.12	-	98.70±22.50	294.64

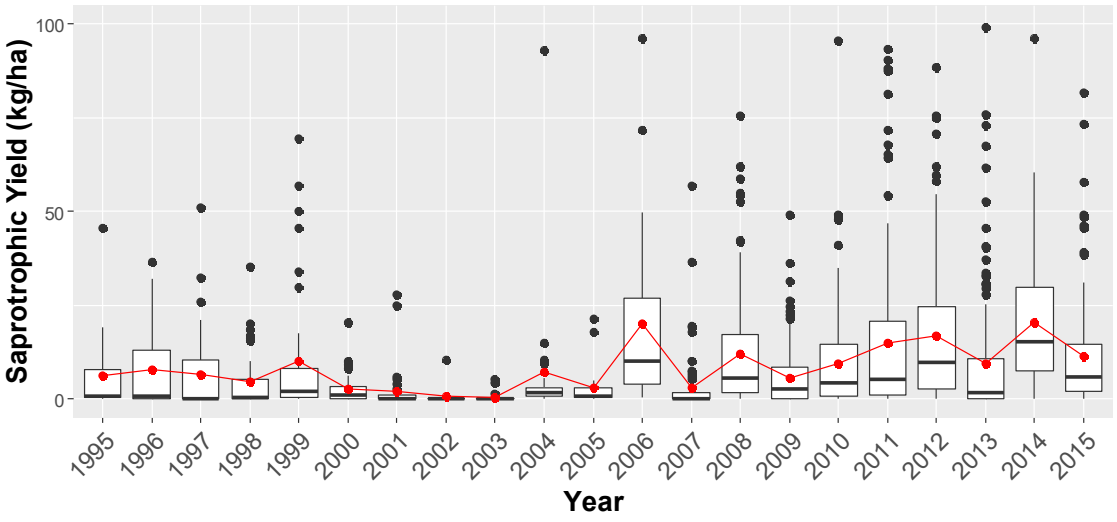
SUPLEMENTARY APPENDIX 3:

Mean annual sporocarps yields and late-summer-early-autumn precipitation and temperature (LSEA) for the 20 years' epigeous sporocarps time-series in Spain: a) total yield (ectomycorrhizal yield is not reported based on the high similarity with total yield), b) saprotrophic yield, c) LSEA precipitation, and d) LSEA temperature. Each boxplot is constructed over total observed values per year. Points and continuous lines indicate yearly mean changes.

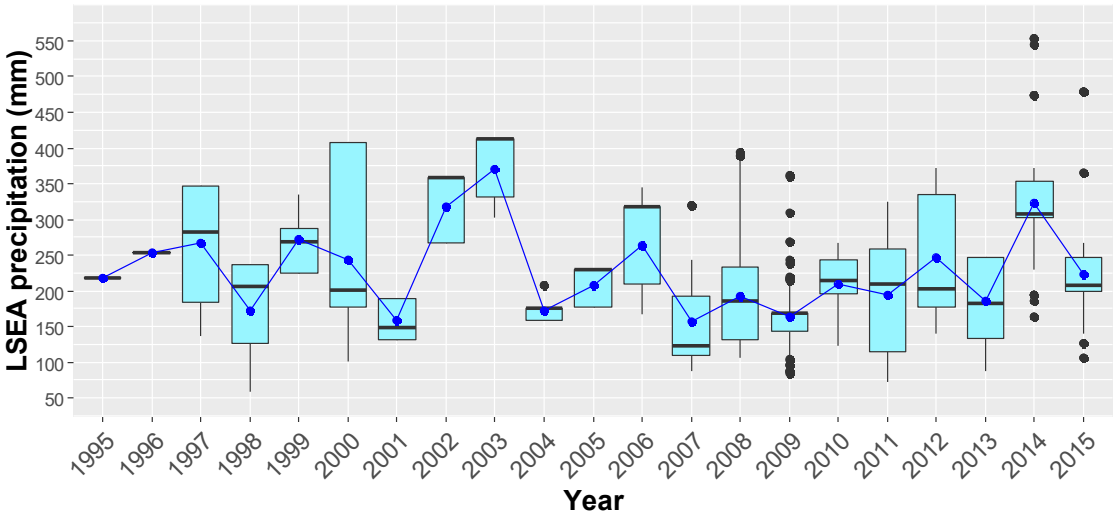
a)



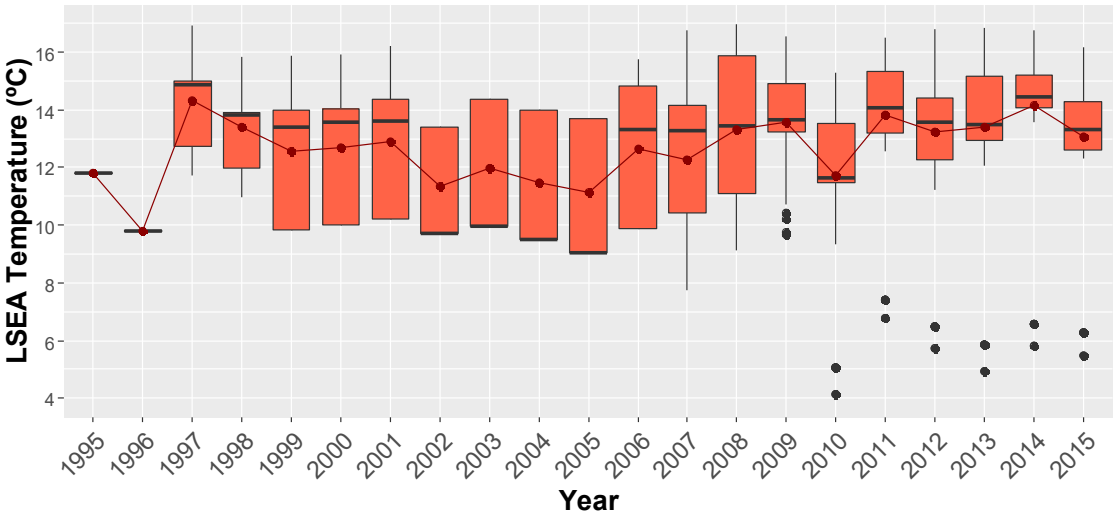
b)



c)


LSEA precipitation (mm)
550
500
450
400
350
300
250
200
150
100
50
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

d)


LSEA Temperature (ºC)
16
14
12
10
8
6
4
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

SUPPLEMENTARY APPENDIX 2:

List of species that have been identified during the monitoring period in the full experimental setup.

Species list (Based on: Index fungorum 9-nov-2016)
Agaricus arvensis Sch.
Agaricus bitorquis (Quél.) Sacc.
Agaricus bresadolanus Bohus
Agaricus campestris L.
Agaricus comtulus Fr.
Agaricus cupreobrunneus (Jul. Schäff. & Steer) Pilát
Agaricus haemorrhoidarius Schulz. ap. Kalchbr
Agaricus impudicus (Rea) Pilát
Agaricus langei (Moll. & J. Schaef.) Moll.
Agaricus osecanus Pilát
Agaricus porphyrizon Orton
Agaricus romagnesii Wasser
Agaricus semotus Fr.
Agaricus sylvaticus Sch.
Agaricus sylvicola (Vitt.) Sacc.
Agaricus urinascens (Jul. Schäff. & F.H. Møller) Singer
Agaricus xanthodermus Genev.
Agrocybe pediades (Fr.) Fayod.
Agrocybe praecox (Pers.) Fayod
Albatrellus ovinus (Schaeff.) Kotl. & Pouzar
Aleuria aurantia (Pers.) Fuck
Amanita battarrae (Boud.) M. Bon
Amanita cistetorum Contu & Pacioni
Amanita citrina (Sch.) Pers.
Amanita echinocephala (Vitt.) Quél.
Amanita eliae Quél.
Amanita excelsa (Fr.) Bertill.
Amanita fulva Fr.
Amanita gracilior Bas & Honrubia
Amanita mairei Foley
Amanita muscaria (L.) Lam.
Amanita ovoidea (Bull.) Link.
Amanita pantherina (DC.) Krombh
Amanita phalloides (Fr.) Link.
Amanita porphyria A.-S.
Amanita proxima Dumée
Amanita rubescens Pers.
Amanita submembranacea (M. Bon) Gröger.
Amanita vaginata (Bull.) Vitt.
Amanita verna (Bull.) Lamk.

Ampulloclitocybe clavipes (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys
Armillaria mellea (Vahl.) Kumm.
Armillaria tabescens (Scop.) Emel.
Arrhenia griseopallida (Desm.) Watling
Arrhenia lobata (Pers.) Kühner & Lamoure ex Redhead
Arrhenia obscurata (D.A. Reid) Redhead, Lutzoni, Moncalvo & Vilgalys
Arrhenia onisca (Fr.) Redhead, Lutzoni, Moncalvo & Vilgalys
Arrhenia rickenii (Hora) Watling,
Arrhenia spathulata (Fr.: Fr.) Redh.
Arrhenia sphagnicola (Berk.) Redhead, Lutzoni, Moncalvo & Vilgalys
Astraeus hygrometricus (Pers.) Morg.
Atheliachaete sanguinea (Fr.) Spirin & Zmitr.
Atheniella adonis (Bull.) Redhead, Moncalvo, Vilgalys, Desjardin & B.A. Perry
Atheniella flavoalba (Fr.) Redhead, Moncalvo, Vilgalys, Desjardin & B.A. Perry
Atheniella leptophylla (Peck) Gminder & T. Böhning
Atractosporocybe inornata (Sowerby) P. Alvarado, G. Moreno & Vizzini
Aureoboletus gentilis (Quél.) Pouz
Aureoboletus moravicus (Vacek) Klofac
Auricularia auricula-judae (L.) Schroet.
Auriscalpium vulgare S.F. Gray.
Baeospora myosura (Fr.) Sing.
Bogbodia uda (Pers.) Redhead
Boletopsis leucomelaena (Persoon) Fayod
Boletus aereus Bull.
Boletus edulis Bull.
Boletus ferrugineus Schaeff.
Boletus pinophilus Pil. & Derm.
Boletus subtomentosus L.
Bonomyces sinopicus (Fr.) Vizzini
Bovista aestivalis (Bonord.) Demoulin
Bovista nigrenscens Pers.
Bovista plumbea Pers.
Butyriboletus appendiculatus (Schaeff.) D. Arora & J.L. Frank
Caloboletus radicans (Pers.) Vizzini
Calocera viscosa (Pers.) Fr.
Calocybe gangraenosa (Fr.) V. Hofst., Moncalvo, Redhead & Vilgalys
Camarophyllus russo-coriaceus (Berk. & Miller) Lange.
Cantharellula umbonata (J.F. Gmel.) Singer
Cantharellus cibarius Fr.
Cantharellus subpruinosus Eyssart. & Buyck
Chalciporus pierrhuguesii (Boud). Bat
Chalciporus piperatus (Bull.) Bat.
Chlorophyllum venenatum (Bon) C. Lange & Vellinga
Chroogomphus fulmineus (Heim) Courtecuisse
Chroogomphus helveticus (Sing.) Moser.
Chroogomphus rutilus (Schaeff.) O.K. Mill.

Clathrus ruber Pers.
Clavaria fumosa Fr.
Clavariadelphus pistillaris (L.) Donk
Clavariadelphus truncatus (Quél) Donk.
Clavulina coralloides (L.) J. Schröt.
Clavulina rugosa (Bull.) J. Schröt.
Clavulinopsis cinerioides (Atk.) Corner syn.
Clavulinopsis corniculata (Sch.) Corner
Clitocybe agrestis Harmaja
Clitocybe alexandri (Gill.) Konrad.
Clitocybe amarescens Harmaja
Clitocybe angustifolia (Kauffman) H.E. Bigelow
Clitocybe brumalis (Bull.: Fr.) Kumm.
Clitocybe candida Bres.
Clitocybe cistophila Bon & Contu
Clitocybe collina (Velen.) Klan
Clitocybe costata Kühner & Romagn
Clitocybe diatreta (Fr.) Kumm.
Clitocybe dicolor (Pers.) Lange
Clitocybe ditopa (Fr.) Gillet
Clitocybe fragrans (With.) Kumm.
Clitocybe gibba (Pers.) Kumm.
Clitocybe gigateus (Sow. Ex Fr.) Quél.
Clitocybe houghtonii (Berk. & Br.) Dennis
Clitocybe hydrogramma (Bull. ex Fr.) Kumm.
Clitocybe infundibuliformis (Schaeff. ex Weinm.) Quél.
Clitocybe langei Singer ex Hora
Clitocybe leucodiatreta Bon
Clitocybe metachroa (Fr.) Kumm.
Clitocybe nebularis (Batsch. ex Fr.) Kumm.
Clitocybe odora (Bull.) Kumm.
Clitocybe phaeophthalma (Pers.) Kuyper
Clitocybe phyllophila (Pers.) P. Kumm.
Clitocybe prunulus (Scop. ex Fr.) Kummer
Clitocybe radicellata Godey
Clitocybe rivulosa (Pers.) Kumm.
Clitocybe robusta Peck.
Clitocybe squamulosa (Pers.) Kumm.
Clitocybe subalutacea (Batsch) Kumm.
Clitocybe vibecina (Fr.) Quél.
Clitopilus hobsonii (Bk. & Br.) Orton
Clitopilus prunulus (Scop.) Kumm.
Clitopilus scyphoides (Fr.) Sing.
Collybia cirrhata (Schumach.) Quél.
Collybia cookei (Bres.) J.D. Arnold
Conocybe aporos Kits van Wav.

Conocybe brunneola Kühn. & Watl.
Conocybe filaris (Fr.) Kühn.
Conocybe ochracea (Kühn.) Sing.
Conocybe pilosella (Pers.) Kühn
Conocybe pseudopilosella Kühn. & Watl.
Conocybe pygmaeoaffinis (Fr.) Kühne
Conocybe subovalis Kühn. & Watl.
Conocybe tenera (Sch.) Fayod.
Contumyces rosellus (M.M. Moser) Redhead, Moncalvo, Vilgalys & Lutzoni
Coprinellus disseminatus (Pers.) J.E. Lange
Coprinellus micaceus Bull.
Coprinopsis atramentaria (Bull.) Redhead, Vilgalys & Moncalvo
Coprinopsis nivea (Pers.) Redhead, Vilgalys & Moncalvo
Coprinopsis picacea (Bull.) Redhead, Vilgalys & Moncalvo
Coprinus comatus (Müll.) Pers.
Coprinus lagopus (Fr.) Fr.
Coprinus sterquilinus (Fr.) Fr.
Cortinarius acutus (Pers.) Fr.
Cortinarius alboviolaceus (Pers.: Fr.) Fr.
Cortinarius anomalus (Fr.) Fr.
Cortinarius assiduus Mahiques, A. Ortega & Bidaud
Cortinarius atrovirens Kalchbr
Cortinarius balteatocumatilis Rob. Henry
Cortinarius balteatus (Fr.) Fr.
Cortinarius betuletorum (Moser) Moser
Cortinarius brunneus (Pers.) Fr.
Cortinarius bulbosus Fr. s. Rick
Cortinarius caerulescens (Sch.) Fr
Cortinarius caesiostramineus Rob. Henry
Cortinarius callochrous (Pers.) Gray
Cortinarius camphoratus (Fr.) Fr.
Cortinarius caninus (Fr.) Fr.
Cortinarius causticus Fr.
Cortinarius chrysolitus Kauffman
Cortinarius cinnamomeoluteus Orton
Cortinarius cinnamomeus (L.) Fr.
Cortinarius coerelescens (Schff. ex Secr.)
Cortinarius collinitus (Sow.) Fr.
Cortinarius cotoneus Fr.
Cortinarius croceocoeruleus (Pers.) Fr.
Cortinarius croceus (Schaeff.) Gray
Cortinarius crystallinus Fr. ss. Bres.
Cortinarius decipiens (Pers.) Fr.
Cortinarius delibutus Fr.
Cortinarius depressus Fr.
Cortinarius diabolicus (Fr.: Fr.) Fr.

Cortinarius diosmus Kühn
Cortinarius eburneus (Velen.) Rob. Henry
Cortinarius elegantior (Fr.) Fr.
Cortinarius elegantissimus Rob. Henry
Cortinarius eustriatulus Hry.
Cortinarius evernius (Fr.) Fr.
Cortinarius flexipes (Pers.) Fr.
Cortinarius fragrantior Gaug.
Cortinarius fulgens Fr.
Cortinarius fulmineus (Fr.) Fr.
Cortinarius glaucopus (Sch.) Fr.
Cortinarius hemitrichus (Pers.) Fr.
Cortinarius herbarum Hry.
Cortinarius hercynicus (Pers.) Moser.
Cortinarius infractus (Pers.) Fr.
Cortinarius largus Fr.
Cortinarius limonius (Fr.) Fr.
Cortinarius mairei (Mos.) Mos.
Cortinarius malachius (Fr. ex Fr.) Fr. s. Kühn & Romang
Cortinarius mucifluus Fr.
Cortinarius mucosus (Bull.) Kickx.
Cortinarius multiformis Fr.
Cortinarius nanceiensis R. Maire
Cortinarius obtusus Fr.
Cortinarius ochroleucus (Sch.) Fr.
Cortinarius odorifer Britz.
Cortinarius orellanus Fr.
Cortinarius osmophorus Orton
Cortinarius paranomalus Hry.
Cortinarius percomis Fr.
Cortinarius poecilopus R. Henry
Cortinarius pratensis (M. Bon & Gaugué) Hoil.
Cortinarius privignus (Fr.) Fr.
Cortinarius pulchripes Favre.
Cortinarius purpurascens (Fr.) Fr
Cortinarius purpureus (Bull.) Bidaud, Moënne-Locc. & Reumaux
Cortinarius rapaceus Fr.
Cortinarius rigens (Pers.) Fr
Cortinarius sanguineus (Wulf.) Fr.
Cortinarius saniosus (Fr.) Fr.
Cortinarius saturninus (Fr.) Fr.
Cortinarius scobinaceus Malençon & Bertault
Cortinarius semisanguineus (Fr.) Gill.
Cortinarius sodagnitus Hry.
Cortinarius solitarius (Fr.) Fr.
Cortinarius spadiceus Fr.

Cortinarius sphagnogenus (Moser) Nespiak.
Cortinarius splendens Hry.
Cortinarius suberetorum R.Maire
Cortinarius subfulgens Orton
Cortinarius subtomentosus Reum.
Cortinarius suillus Fr.
Cortinarius sulphureus Lindgr.
Cortinarius sulphurinus Quél.
Cortinarius talus Fr.
Cortinarius triumphans Fr
Cortinarius trivialis Lge.
Cortinarius uliginosus Berk
Cortinarius variicolor (Pers.) Fr.
Cortinarius venetus (Fr.) Fr.
Cortinarius vibratilis (Fr.: Fr.) Fr.
Cortinarius xanthocephalus Orton
Cortinarius xerophilus Rob. Henry & Contu
Craterellus cornucopioides (L.) Pers.
Craterellus lutescens (Fr.) Fr.
Crepidotus applanatus (Pers.) P. Kumm.
Crepidotus luteolus (Lamb.) Sacc.
Crepidotus variabilis (Pers.) Kumm
Crinipellis scabella (Alb. & Schwein.) Murrill
Crucibulum laeve (Bull.) Klamby.
Cryptomarasmius minutus (Peck) T.S. Jenkinson & Desjardin
Cudonia circinans (Pers.) Fr.
Cudonia confusa Bres.
Cuphophyllus fornicatus (Fr.) Lodge, Padamsee & Vizzini
Cuphophyllus pratensis (Fr.) Bon
Cuphophyllus virgineus (Wulfen) Kovalenko
Cyanoboletus pulverulentus (Opat.) Gelardi, Vizzini & Simonini
Cyathus olla (Batsch) Pers.
Cystoderma amianthinum (Scop.) Fayod.
Cystoderma carcharias (Pers.) Fayod.
Cystoderma cinnabarinum (A.-S.) Fr. Harmaja
Cystoderma granulosum (Batsc: Fr.h) Fayod
Cystoderma superbum Fayod
Cystodermella cinnabarina (Alb. & Schwein.) Harmaja
Cystodermella granulosa (Batsch) Harmaja
Cystodermella terryi (Berk. & Broome) Bellù
Cystolepiota adulterina (F.H. Møller) Bon
Cystolepiota cystophora (Malç.) M. Bon.
Cystolepiota seminuda (Lasch.) M. Bon.
Dacrymyces stillatus Ness: Fr.
Deconica merdaria (Fr.) Noordel.
Delicatula integrella (Pers.) Fayod

Dermoloma cuneifolium (Fr.) Singer ex Bon
Dermoloma pseudocuneifolium Herink ex M. Bon
Echinoderma asperum (Pers.) M. Bon.
Echinoderma echinaceum (Lange) M. Bon.
Echinoderma eriophorum (Peck) M. Bon.
Entocybe nitida (Quél.) T.J. Baroni, Largent & V. Hofst.
Entoloma araneosum (Quél) Mosel
Entoloma bisporigenum (Kühner) Noordel.
Entoloma bloxamii (Bk. & Br.) Sacc.
Entoloma cetratum (Fr.) Moser.
Entoloma chalybeum (Pers.) Noordel.
Entoloma cistophilum Trimbach
Entoloma conferendum (Britzelm.) Noordel.
Entoloma dysthales (Peck) Sacc.
Entoloma elodes (Fr.) Kumm.
Entoloma excentricum Bres.
Entoloma formosum (Fr.:Fr.)
Entoloma hebes (Romagn.) Trimbach
Entoloma hirtipes (Schumach.) M.M. Moser
Entoloma incanum (Fr.) Hesler
Entoloma infula (Fr.) Noordel.
Entoloma juncinum (Kühn. & Romagn.)
Entoloma longistriatum (Peck) Noordel.
Entoloma minutum (P. Karst.) Noord.
Entoloma mougeotii (Fr.) Hesl.
Entoloma papillatum (Bres.) Dennis
Entoloma plebejum (Kalchbr.) Noord.
Entoloma pleopodium (Bull.) Noordel.
Entoloma porphyrophaeum (Fr.) P. Karst.
Entoloma rhodopolium (Fr.) P. Kumm.
Entoloma roseum (Longyear) Moser
Entoloma sepium (Noulet & Dass.) Richon & Roze
Entoloma sericeum (Bull.) Quél.
Entoloma serrulatum (Fr.) Hesler
Entoloma sinuatum (Bull.) P. Kumm.
Entoloma sordidulum (Kühner & Romagn.) Orton.
Entoloma subradiatum (Kühner & Romagn.) Moser.
Entoloma turci (Bres.) Moser
Entoloma undatum (Fr.) Moser.
Entoloma vernum S. Lundell
Entoloma versatile (Gillet) M.M. Moser
Exidia saccharina Fr.
Fayodia gracilipes (Britzelm.) Bresinsky & Stangl
Flamulaster carpophilus (Fr.) Earle ex Vellinga
Galerina badipes (Fr.) Kiihn.
Galerina earle (Fr.) Sing.

Galerina embolus (Fr.) P.D. Orton
Galerina fallax A.H. Sm. & Singer
Galerina graminea (Velen.) Kühner
Galerina hypnorum (Schrank) Kühner
Galerina marginata (Batsch) Kühn.
Galerina mycenoides (Fr.) Kühn.
Galerina paludosa (Fr.) Kühn
Galerina praticola (Møll.) Orton.
Galerina pumila (Pers.) Lange ex Sing.
Galerina sideroides (Bull.) Kühn.
Galerina sphagnorum (Pers.) Kühn.
Galerina stylifera (Atk.) A. H. Smith & Sing.
Galerina uncialis (Britz.) Kühn.
Galerina vittiformis (Fr.) Singer
Ganoderma lucidum (Leyss) P. Karst.
Geastrum fimbriatum Fr.
Geastrum hygrometricum Pers.
Geastrum molle Pers.
Geastrum quadrifidum Pers.
Geastrum rufescens Pers.
Geastrum saccatum Fr.
Geastrum triplex Jungh.
Geopora sumneriana (Cooke) M. Torre
Gliophorus laetus (Pers.) Herink
Gomphus clavatus (Pers.) S.F.Gray
Gomphus roseus (Nees:Fr.) Gillet
Guepinia helvelloides (DC.) Fr.
Gymnopilus decipiens (Sacc.) P.D. Orton
Gymnopilus fulgens (Favre & Maire) Sing
Gymnopilus hybridus (Fr. ex Fr.) Sing.
Gymnopilus penetrans (Fr.) Murr
Gymnopilus stabilis ((Weinm.) K.-R. ex M. Bon
Gymnopus androsaceus (L.) Della Maggiora & Trassinelli
Gymnopus aquosus (Bull.) Antonín & Noordel.
Gymnopus brassicolens (Romagn.) Antonín & Noordel
Gymnopus dryophilus (Bull.) Murrill
Gymnopus erythropus (Pers.) Antonín, Halling & Noordel
Gymnopus foetidus (Sowerby) P.M. Kirk
Gymnopus fusipes (Bull.) Gray
Gymnopus hariolorum (Bull.) Antonín, Halling & Noordel.
Gymnopus impudicus (Fr.) Antonín, Halling & Noordel.
Gymnopus ocior (Pers.) Antonín & Noordel.
Gymnopus oreadoides (Pass.) Antonín & Noordel.
Gymnopus perforans (Hoffm.) Antonín & Noordel.
Gymnopus peronatus (Bolton) Gray
Gyromitra esculenta (Pers.) Fr.

Gyromitra infula (Sch.) Quél.
Gyroporus castaneus (Bull.) Quél
Hebeloma cistophilum Maire
Hebeloma crustuliniforme (Bull. ex St. Amans) Quél.
Hebeloma cylindrosporum Romagn.
Hebeloma hiemale Bres.
Hebeloma laterinum (Batsch) Vesterh.
Hebeloma leucosarx Orton
Hebeloma mesophaeum (Pers.) Quél.
Hebeloma psammophilum Bon.
Hebeloma sacchariolens Quél.
Hebeloma sinapizans (Paul.) Gill.
Helvella crispa (Scop.) Fr.
Helvella lacunosa Afz.
Hemileccinum impolitum (Fr.) Šutara
Hemimycena cucullata (Pers.) Sing
Hemimycena lactea (Pers.) Singer
Hemimycena mairei (Gilb.) Sing.
Hohenbuehelia petaloides (Bulliard) Schulzer
Humaria hemisphaerica (Eigg.) Fuck.
Hydnellum aurantiacum (Batsch: Fr.) P. Karst.
Hydnellum concrescens (Pers. ex Schw.) Banker
Hydnellum ferrugineum (Fr.:Fr.) P. Karst.
Hydnellum scrobiculatum (Fr. ex Secr.) Karst.
Hydnellum spongiosipes (Peck) Pouzar
Hydnum repandum L.
Hydnum rufescens Pers.
Hydropus omphaliiformis (Kühner) Honrubi
Hygrocybe acutoconica (Clem.) Singer
Hygrocybe chlorophana (Fr.) Wünsche
Hygrocybe coccinea (Sch.) Kumm.
Hygrocybe conica (Scop.) Kumm.
Hygrocybe intermedia (Pass.) Fayod
Hygrocybe marchii (Bres.) Moll.
Hygrocybe miniata (Fr.) M. Kumm
Hygrocybe ovina (Bull.) Kühn.
Hygrophoropsis aurantiaca (Wolf.) R. Maire
Hygrophorus agathosmus (Fr.) Fr.
Hygrophorus arbustivus (Fr.) Fr.
Hygrophorus atramentosus (Secr.) Haas et Haller
Hygrophorus camarophyllus (Alb. & Schwein.) Dumée, Grandjean & Maire
Hygrophorus chrysodon (Batsch) Fr.
Hygrophorus cossus (Sow.) Fr.
Hygrophorus eburneus (Bull.) Fr.
Hygrophorus gliocyclus Fr.
Hygrophorus hypothejus (Fr.: Fr.) Fr.

Hygrophorus latitabundus Britz.
Hygrophorus pseudodiscoideus (Maire) Malençon & Bertault
Hygrophorus russula (Sch.) Quél.
Hypholoma capnoides (Fr.) Kumm.
Hypholoma elongatum (Pers.) Ricken
Hypholoma ericaeoides Orton
Hypholoma fasciculare (Huds.) Kumm.
Hypholoma lateritium (Schaeff.) P. Kumm
Hypholoma marginatum (Pers.) Schroet.
Hypholoma radicosum Lange
Hypomyces lateritius (Fr.) Tul.
Hypoxylon fragiforme (Pers.) J. Kickx f.
Imperator torosus (Fr.) Assyov, Bellanger, Bertéa, Courtec., G. Koller, Loizides, G. Marques, J.A. Muñoz, N. Oppicelli, D. Puddu, F. Rich. & P.-A. Moreau
Inocybe abietis Kühn
Inocybe abjecta (P. Karst.) Sacc.
Inocybe adaequata (Britzelm.) Sacc.
Inocybe aeruginascens Babos
Inocybe agardhii (Lund.) Orton
Inocybe arenicola (R. Heim) Bon
Inocybe assimilata Britzelm.
Inocybe asterospora Quél.
Inocybe bongardii (Weinm.) Quél.
Inocybe calospora Quél.
Inocybe cervicolor (Pers.) Quél.
Inocybe cincinnata (Fr.) Quél.
Inocybe conica Larsen
Inocybe cookei Bres.
Inocybe dulcamara (A.-S.) Kumm.
Inocybe dunensis Orton.
Inocybe erubescens A. Blytt
Inocybe fibrosa (Sow.) Gill.
Inocybe flocculosa (Berk.) Sacc
Inocybe fraudans (Britzelm.) Sacc
Inocybe fuscidula Velen
Inocybe geophylla (Bull.) Kumm.
Inocybe glabripes Ricken
Inocybe godeyi Gill.
Inocybe grammata Quél.
Inocybe griseolilacina Lange
Inocybe griseovelata Kühn.
Inocybe heimii Bon.
Inocybe hirtella Bres.
Inocybe lacera (Fr.) P. Kumm.
Inocybe maculata Boud.
Inocybe mixtilis (Britz.) Sacc.

Inocybe napipes Lange
Inocybe nitidiuscula (Britz) Sacc.
Inocybe pelargonium Kühner
Inocybe petiginosa (Fr.) Gill.
Inocybe phaeodisca Kühn.
Inocybe phaeoleuca Kühn.
Inocybe piriodora (Britz.) Sacc.
Inocybe praetervisa Quél.
Inocybe rimosa (Bull.:Fr.) Kumm.
Inocybe serotina Peck
Inocybe sindonia (Fr.) P. Karst.
Inocybe terrigena (Fr.) Kühn
Inocybe vaccina Kühn.
Inocybe whitei (Berk. & Broome) Sacc.
Kuehneromyces mutabilis (Schaeff.) Singer & A.H. Sm.
Laccaria amethystina (Huds.) Cke
Laccaria bicolor (Maire) P.D. Orton
Laccaria fraterna (Cke. & Mass.)
Laccaria laccata (Scop.) Cooke
Laccaria proxima (Boud.) Pat.
Lacrymaria lacrymabunda (Bull.) Pat.
Lactarius acerrimus Britz.
Lactarius acris (Bolton) Gray.
Lactarius atlanticus Bon
Lactarius aurantiacus (Pers.) Gray
Lactarius bertillonii (Nhf. Ex Z. Sch) Bon
Lactarius camphoratus (Bull.) Fr.
Lactarius chrysorrheus Fr.
Lactarius cistophilus Bon & Trimbach
Lactarius decipiens Quél.
Lactarius deliciosus (L.) S. F. Gray
Lactarius glyciosmus (Fr.) Fr.
Lactarius hepaticus Plowr.
Lactarius lilacinus (Lasch) Fr.
Lactarius picinus Fr.
Lactarius quietus (Fr.:Fr.) Fr.
Lactarius rufus (Scop.) Fr.
Lactarius sanguifluus (Paul.) Fr.
Lactarius scrobiculatus (Scop.) Fr.
Lactarius semisanguifluus Heim & Lecl.
Lactarius serifluus (DC.: Fr.) Fr.
Lactarius sphagneti (Fr.) Nhf.
Lactarius subumbonatus Lindgr.
Lactarius tesquorum Malençon
Lactarius torminosus (Sch.) S.F. Gray.
Lactarius vellereus (Fr.) Fr.

Lactarius vietus (Fr.) Fr.
Lactarius vinosus Quél
Lactarius violascens (Otto) Fr.
Lactarius volemus (Fr.) Fr.
Lactarius zonarius (Bull.) Fr.
Leccinellum corsicum (Rolland) Bresinsky & Manfr. Binder
Leccinellum lepidum (H. Bouchet ex Essette) Bresinsky & Manfr. Binder
Leccinum aurantiacum (Bull.) Gray
Leccinum scabrum (Bull.) Gray
Leccinum versipelle (Fr.) Snell
Lentinellus micheneri (Berk. & M.A. Curtis) Pegle
Leocarpus fragilis (Dicks.) Rostaf.
Lepiota brunneoincarnata Chod. & Mart.
Lepiota castanea Quél.
Lepiota clypeolaria (Bull.) Kumn.
Lepiota cristata (Bolt.) Kumm.
Lepiota erminea (Fr.) P. Kumm.
Lepiota felina (Pers.) P. Karst.
Lepiota forquignonii Quél.
Lepiota griseovirens R. Maire
Lepiota helveola Bres.
Lepiota ignivolvata Joss.
Lepiota lilacea Bres.
Lepiota magnispora Murrill
Lepiota oreadiformis Vel.
Lepiota oreadiformis Velen.
Lepiota pseudofelina Lange ex Lange
Lepiota subgracilis Kuhn. Ex Wass.
Lepiota subincarnata J.E. Lange
Lepista glaucocana (Bres.) Sing.
Lepista nuda (Bull.) Cke.
Lepista panaeolus (Fr.) P. Karst
Lepista sordida (Schumach.) Sing.
Leratiomyces squamosus (Pers.) Bridge & Spooner
Leucoagaricus barssii (Zeller) Vellinga
Leucoagaricus leucothites (Vitt.) Wasser
Leucoagaricus pilatianus (Demoulin) Bon.
Leucoagaricus sublittoralis (Kühn, ex Hora) Sing.
Leucoagaricus wichanskyi Pilát) Bon & Boiffard.
Leucocoprinus brebissonii (Godey) Locquin
Leucocybe candicans (Pers.) Vizzini, P. Alvarado, G. Moreno & Consiglio
Leucocybe connata (Schumach.) Vizzini, P. Alvarado, G. Moreno & Consiglio
Leucopaxillus gentianeus (Quél.) Kotl.
Leucopaxillus giganteus (Leyss.) Sing.
Leucopaxillus tricolor (Peck.) Kuhn
Lichenomphalia umbellifera (L.) Redhead, Lutzoni, Moncalvo & Vilgalys

Limacella guttata (Pers.:Fr.) Konrad & Maublanc
Limacella illinita (Fr.) Murr.
Lycogala epidendrum L.
Lycoperdon echinatum Pers.
Lycoperdon excipuliforme (Scop.) Pers.
Lycoperdon lividum Pers.
Lycoperdon molle Pers.
Lycoperdon nigrescens Pers.
Lycoperdon perlatum Pers.
Lycoperdon pratense Pers.
Lycoperdon pyriforme Sch.
Lycoperdon spadiceum Pers.
Lycoperdon umbrinum Pers.
Lyophyllum decastes (Fr.) Sing.
Lyophyllum infumatum (Bres.) Kühner
Lyophyllum loricatum (Fr.) Kühn.
Lyophyllum semitale (Fr.) Kühner
Macrocystidia cucumis (Pers.) Joss.
Macrolepiota excoriata (Schaeff.) M.M. Moser
Macrolepiota gracilenta (Krombh.) Wasser
Macrolepiota konradii (Huijsm. Ex Orton) Moser
Macrolepiota mastoidea (Fr.) Singer
Macrolepiota procera (Scop.) Sing.
Macrolepiota rachodes (Vittad.) Singer
Marasmius cohaerens (Pers.) Cke. & Quél.
Marasmius curreyi Berk. & Broome
Marasmius epiphyllus (Pers.) Fr.
Marasmius rosella (Bolt.) Fr.
Marasmius rotula (Scop.) Fr.
Marasmius torquescens Quél.
Marasmius wynneae Bk. & Br.
Megacollybia platyphylla (Pers.) Kotl. & Pouz.
Melanoleuca cognata (Fr.) K. & M.
Melanoleuca exscissa (Fr.:Fr.) Sing
Melanoleuca grammopodia (Bull.) Pat.
Melanoleuca leucophylloides (Bon) Bon
Melanoleuca melaleuca (Pers.) Murr.
Melanoleuca polioleuca (Fr.) Kühner & Maire
Melanoleuca pseudoluscina M. Bon.
Melanoleuca verrucipes (Fr. Ap. Quél.) Sing.
Melanophyllum eyrei (Mass.) Sing.
Meottomyces dissimulans (Berk. & Broome) Vizzini
mleria badia (Fr.) Vizzini
Mutinus caninus (Huds.) Fr.
Mycena acicula (Sch.) Kumm.
Mycena aetites (Fr.) Quél.

Mycena alcalina (Fr.) Kumm.
Mycena algeriensis Maire
Mycena amicta (Fr.) Quél.
Mycena ammoniaca (Fr.) Quél.
Mycena arcangeliana Bres.
Mycena aurantiomarginata (Fr.) Quél.
Mycena bryophila Voglino
Mycena capillaripes Peck
Mycena capillaris (Shum.) Kumm.
Mycena cinerella (P. Karst.) P. Karst.
Mycena clavicularis (Fr.) Gillet
Mycena crocata (Schrad.:Fr.) Kumm.
Mycena epipterygia (Scop.) Gray
Mycena epipterygioides Pears.
Mycena erubescens Höhn.
Mycena filopes (Bull.) Kumm.
Mycena flavescens Vel.
Mycena galericulata (Scop.) S.F. Gray.
Mycena galopus (Pers.) Kumm.
Mycena haematopus (Pers.:Fr.) Kumm.
Mycena inclinata (Fr.) Quél.
Mycena laevigata (Lasch.) Quél.
Mycena leptocephala (Pers.) Gill.
Mycena leucogala (Cooke) Sacc.
Mycena maculata P.Karst.
Mycena meliigena (Berk. & Che.)
Mycena metata (Secr. ex Fr.) P. Kumm.
Mycena olivaceomarginata (Mass.) Mass.
Mycena polygramma (Bull.) S.F. Gray
Mycena pseudocorticola Kühn.
Mycena pseudopicta (J.E. Lange) Kühner
Mycena pura (Pers.) Kumm.
Mycena rosea (Bull.) Gramb.
Mycena rosella (Fr) Kumm.
Mycena sanguinolenta (Alb. & Schw.:Fr.) Kumm.
Mycena seynii Quél.
Mycena silvae-nigrae Maas Geest. & Schwöbel
Mycena ustalis Aronsen & Maas Geest.
Mycena viridimarginata P. Karst.
Mycena vitilis (Fr.) Quél.
Mycena vulgaris (Pers.) Kumm.
Mycena zephirus (Fr.) Kumm.
Mycenella bryophila (Vogl.)
Mycetinis alliaceus (Jacq.) Earle ex A.W. Wilson & Desjardin
Mycetinis scorodonius (Fr.) A.W. Wilson & Desjardin
Myxomphalia maura (Fr.) Hora.

Naucoria bohemica (Vel.) Sing.
Naucoria scolecina (Fr.) Quél.
Neoboletus erythropus (Pers.) C. Hahn
Omphaliaster asterosporus (J.E. Lange) Lamoure
Omphalina pseudoclusilis (Joss. & Konrad) Raithel.
Omphalina pyxidata (Bull.:Fr.) Quél
oprinellus congregatus (Bull.) P. Karst
Ossicaulis lignatilis (Pers.) Redhead & Ginns
Otidea alutacea (Pers) Mass
Otidea onotica (Pers.)
Panaeolus fimicola (Pers.) Quél.
Panaeolus papilionaceus (Bull.) Quél.
Panaeolus rickenii Hora
Panaeolus semiovatus (Sowerby) S. Lundell & Nannf.
Paralepista flaccida (Sowerby) Vizzini
Paralepista gilva (Pers.) Vizzini
Parasola plicatilis (Curtis) Redhead, Vilgalys & Hopple
Paxillus involutus (Batsch) Fr.
Peziza badia Pers.
Peziza micropus Pers.
Peziza vesiculosa Bull
Phaeoclavulina abietina (Pers.) Giachini
Phaeocollybia christinae (Fr.) Heim
Phaeolepiota aurea (Matt.) Maire
Phaeolus schweinitzii (Fr.) Pat.
Phaeomarasmius erinaceus (Fr.) Scherff. ex Romagn.
Phallus impudicus L.
Phellodon niger (Fr.) P. Karst.
Phellodon tomentosus (L.) Banker
Phloeomana minutula (Sacc.) Redhead
Phloeomana speirea (Fr.) Redhead
Pholiota alnicola (Fr.) Sing.
Pholiota aurivella (Batsch) P. Kumm
Pholiota conissans (Fr.) M.M. Moser,
Pholiota flavida (Sch.) Sing.
Pholiota gummosa (Lasch) Sing.
Pholiota highlandensis (Peck.) A.H. Smith & Hesl.
Pholiota lenta (Pers.) Sing.
Pholiota ochrochlora (Fr.) Orton
Pholiota squarrosa (Müll.) Humm.
Pholiota tuberculosa (Schaeff.) P. Kumm.
Pisolithus arhizus (Scop.) Rauschert,
Pleurotus ostreatus (Jacq.) P. Kumm
Pluteus atromarginatus (Konrad) Kühner
Pluteus cervinus (Sch.) ex Kumm.
Pluteus cinereofuscus Lange.

Pluteus nanus (Pers.:Fr.) Kumm.
Pluteus phlebophorus (Ditm.) Kumm
Pluteus plautus (Weinm.) Gillet
Pluteus romellii (Britz.)
Pluteus roseipes Höhnel
Pluteus salicinus (Pers. Ex Fr.) Kummer
Pluteus semibulbosus (Lasch) Gill.
Pluteus thomsonii (Bk. & Br.) Dennis
Postia hibernica (Berk. & Broome) Jülich
Postia stiptica (Pers.) Jülich
Protostropharia luteonitens (Fr.) Redhead
Protostropharia semiglobata (Batsch) Redhead, Moncalvo & Vilgalys
Psathyrella candolleana (Fr.) R. Maire
Psathyrella corrugis (Pers.) Konrad & Maubl.
Psathyrella maculata (Parker) A.H. Smith
Psathyrella multipedata (Peck.) A. H. Sm.
Psathyrella piluliformis (Bull.) P.D. Orton
Pseudoclitocybe cyathiformis (Bull.) Singer
Pseudoclitocybe expallens (Pers.) Moser.
Pseudoomphalina compressipes (Peck) Sing.
Psilocybe coprophila (Bull.) Kumm.
Psilocybe coronilla (Bull.) Noordel.
Psilocybe crobula (Fr.) Singer
Psilocybe inquilina (Fr.) Bres.
Psilocybe montana (Pers.) Kumm.
Ramaria aurea (Sch.) Quél.
Ramaria flava (Fr.) Quél.
Ramaria flavoides Schild
Ramaria formosa (Pers.: Fr.) Quél.
Ramaria gracilis (Pers.: Fr.) Quél.
Ramaria mairei Donk
Ramaria stricta (Pers.) Quél.
Rheubarbariboletus armeniacus (Quél.) Vizzini, Simonini & Gelardi
Rhizomarasmius undatus (Berk.) R.H. Petersen
Rhizopogon luteolus Fr.
Rhizopogon roseolus (Corda) Th. Fr.
Rhodocollybia butyracea (Bull.) Kumm.
Rhodocollybia maculata (A.-S.) Kumm.
Rhodocollybia prolixa (Fr.) Antonín & Noordel.
Rhodocybe truncata (Schaeff.) Singer
Rickenella fibula (Singer & Clem.) Lamoure
Ripartites tricholoma (Alb. & Schwein.) P. Karst
Rugosomyces carneus (Bull.) Bon
Rugosomyces ionides (Bull.) Bon
Russula acrifolia Romagn.
Russula adusta (Pers.) Fr.

Russula aeruginea Lindbl.
Russula albonigra (Krombh.) Fr.
Russula alutacea (Pers.) Fr.
Russula amethystina Quél.
Russula amoena Quél.
Russula amoenicolor Romagn.
Russula amoenolens Romagn.
Russula anthracina Romagn.
Russula atropurpurea Krombh.
Russula aurea Pers.
Russula badia Quél.
Russula brunneoviolacea Crawsh.
Russula caerulea Fr.
Russula carminipes Blum
Russula cessans Pears.
Russula chloroides (Kromb.) Bres.
Russula cistoadelpha Moser & Trimbach
Russula cuprea (Krombh.) Lange
Russula cyanoxantha (Sch.) Fr.
Russula decipiens (Sing.)
Russula delica Fr.
Russula densifolia Gill.
Russula emetica (Sch.) Pers.
Russula exalbicans (Pers.) Melzer & Zvára
Russula farinipes Romell
Russula fellea (Fr.) Fr.
Russula ferreri Sing
Russula firmula J. Schaef.
Russula foetens Pers.
Russula fragilis (Pers.) Fr.
Russula fuscorubroides Bon.
Russula gracillima Schaeff
Russula grisea Fr.
Russula heterophylla (Fr.) Fr.
Russula ilicis Romagn.
Russula integra (L.) Fr.
Russula intermedia P. Karst.
Russula laeta MØll & Schaef.
Russula langei M. Bon.
Russula luteotacta Rea
Russula maculata Quél. & Roz
Russula monspeliensis Sarnari
Russula mustelina Fr.
Russula nauseosa (Pers.) Fr.
Russula nigricans Fr.
Russula nitida (Pers.) Fr.

Russula nobilis Velen
Russula ochraceoalba Britzelm.
Russula ochroleuca Pers.
Russula odorata Romagn.
Russula olivacea (Sch.) Pers.
Russula paludosa Britz.
Russula prinophila Sarnari
Russula pseudointegra Arn. & Gor.
Russula queletii Fr.
Russula risigallina (Batsch) Sacc.
Russula risigallina var. acetolens (Rauschert) Krieglst.
Russula romellii Maire
Russula rosea Pers.
Russula roseipes Secr. ex Bres.
Russula rubra (Lamk.) Fr.
Russula rubroalba (Sing.) Romagn.
Russula sanguinea (Bull. ex St. Amans) Fr.
Russula sardonia Fr.
Russula subfoetens Smith.
Russula torulosa Bres.
Russula turci Bres.
Russula versicolor Schaef.
Russula vesca Fr.
Russula veternosa Fr.
Russula vinosa Lindb.
Russula violeipes Quél.
Russula virescens (Sch.) Fr.
Russula xerampelina (Sch.) Fr.
Saproamanita vittadinii (Moretti) Redhead, Vizzini, Drehmel & Contu
Sarcodon fuligineoviolaceus (Kalchbr.) Pat.
Sarcodon imbricatum (L. ex Fr.) Karst.
Sarcodon joeides (Pass.) Bat
Sarcodon scabrosus (Fr.) Karst.
Sarcoscypha coccinea (Jacq.) Schroet.
Schizophyllum commune (L.) Fr.
Scleroderma areolatum Ehrenb. Al.
Scutellinia scutellata (L.) Lamb.
Scutiger pes-caprae (Pers.) Bondartsev & Singer,
seudoboletus parasiticus (Bull.) Šutara
Simocybe centunculus (Fr.) Karst.
Spathularia flavida Pers.
Sphagnurus paluster (Peck) Redhead & V. Hofst.
Strobilurus stephanocystis Kühner & Romagn. ex Hora) Singer,
Strobilurus tenacellus (Pers.:Fr.) Singer.
Stropharia aeruginosa (Curt.) Quél.
Stropholoma aurantiacum (Cooke) Ryman

Suillellus luridus (Schaeff.) Murrill
Suillus bellinii (Inz.) Kuntze.
Suillus bovinus (L.) Roussel
Suillus collinitus (Fr.) Kuntze
Suillus granulatus (L.) Roussel.
Suillus luteus (L.) Roussel.
Suillus mediterraneensis (Jacq. & Blum) Redeuilh
Suillus variegatus (Swartz) Rich. & Roze.
Suillus viscidus (L.) Rousse
Syzygospora tumefaciens (Ginns & Sunhede) Ginns
Taiinella panuoides (Fr.) Fr.
Tapinella atrotomentosa (Batsch) Šutara
Tapinella panuoides (Fr.) E.-J. Gilbert
Tarzetta catinus (Holmsk.) Fuck.
Tephrocybe anthracophila (Lasch) Orton.
Tephrocybe confusa (P.D. Orton) P.D. Orton
Tephrocybe palustris (Peck) Donk. Al. Sumpf-Graublatt
Tephrocybe rancida (Fr.) Donk
Thelephora caryophyllea (Schaeff.) Pers.
Thelephora terrestris Ehrh.
Trametes versicolor (L.:Fr.) Quél.
Tremella mesenterica Retz. Ex
Trichaptum abietinum (Pers. ex J.F. Gmel.) Ryv.
Tricholoma acerbum (Bull.) Quél.
Tricholoma albobrunneum (Pers.) P. Kumm.
Tricholoma album (Sch.) Kumm.
Tricholoma atrosquamosum (Chev.) Sacc.
Tricholoma bufonium (Pers.) Gill.
Tricholoma caligatum (Viv.) Ricken.
Tricholoma cinnamomeum (Murrill) Murrill
Tricholoma columbetta (Fr.) Kummer
Tricholoma equestre (L.) Kumm.
Tricholoma focale (Fr.) Ricken.
Tricholoma fracticum (Batsch) Kreisel
Tricholoma fulvum (Bull.: Fr.) Sacc.
Tricholoma gausapatum (FR.) Quél.
Tricholoma imbricatum (Fr.) Kumm.
Tricholoma inamoenum (Fr.) Gill.
Tricholoma orirubens Quél
Tricholoma pessundatum (Fr.) Quél.
Tricholoma portentosum (Fr.) Quél.
Tricholoma psammopus (Kalchbr.) Quél
Tricholoma saponaceum (Fr.) Kumm
Tricholoma scalpturatum (Fr.) Quél.
Tricholoma sciodes (Pers.) Konrad
Tricholoma sejunctum (Sow.) Quél.

Tricholoma squarrulosum Bres.
Tricholoma stans (Fr.) Scacc.
Tricholoma sulphurescens Bres.
Tricholoma terreum (Sch.) Kumm.
Tricholoma triste (Scop.) Quél.
Tricholoma ustale (Fr.) Kumm.
Tricholoma vaccinum (Sch.) Kumm.
Tricholoma virgatum (Fr.) Kumm.
Tricholomella constricta (Fr.) Zerova ex Kalamees
Tricholomopsis decora (Fr.) Sing.
Tricholomopsis rutilans (Sch.) Sing.
Tubaria conspersa (Pers.) Fayod
Tubaria furfuracea (Pers.) Gill.
Tuber rufum Pico
Tyromyces chioneus (Fr.) P. Karst.
Volvariella murinella (Quél.) Moser. al.
Xerocomellus porosporus (Imler ex Bon) Šutara,
Xerocomus chrysenteron (Bull.) Quél.
Xeromphalina cauticinalis (Fr.) Kühner & Maire,
Xerula pudens (Pers.) Singer
Xylaria hypoxylon (L.) Dumort.

SUPPLEMENTARY APPENDIX 1

Different sets of permanents plots were established in pure or mixed forest stands in three different regions in Northern Spain. The size of the plots ranged from 100 m^2 to 150 m^2.

Region	Main species	Number of plots (Years of survey)	Transect/Plots (size)
Catalonian Region (North-eastern)	*Pinus nigra*	11 (1997-2001) (2007-2015) 2 (2007-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Pinus sylvestris*	6 (1997-2001) (2007-2015) 8 (2007-2015) 5 (2008-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Pinus halepensis*	4 (1997-2001)(2007-2015) 2 (2007-2015) 2 (2008-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Pinus sylvestris* *Pinus nigra*	7 (2007-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Pinus nigra* *Pinus halepensis*	4 (2007-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Pinus pinaster*	15 (2008-2015) 13 (2009-2015)	Plot (10 m x 10 m)
Catalonian Region (North-eastern)	*Quercus ilex*	8 (2008-2015)	Plot (10 m x 10 m)
Eastern Castilla y León Region (Eastern-C y L; North-Central)	*Pinus sylvestris*	18 (1995-2015)	Plot (30 m x 5 m)
Eastern Castilla y León Region (Eastern-C y L; North-Central)	*Pinus pinaster*	14 (1997-2015)	Plot (30 m x 5 m)
Western-central Castilla y León Region (Western-C y L; North-Western)	*Pinus sylvestris*	3 (2008-2015)	Plot (2 m x 50 m)
Western-central Castilla y León Region (Western-C y L; North-Western)	*Pinus pinaster*	3 (2003-2006) (2008-2015) 6 (2006-2009) (2011-2015)	Lineal transect (2 m x 50 m)
Western-central Castilla y León Region (Western-C y L; North-Western)	*Cistus ladanifer*	9 (2010-2015)	Lineal transects (2 m x 50 m)